Iowa State Highway Commission
Materials Department
Special Investigations

Research Project R-11-Z(1)
Final Report

A Study of Curing Methods and Type II Cements on the Durability of Concrete

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A Study of Curing Methods and Type II Cements on the Durability of Concrete

by

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1.0 INTRODUCTION

A program of A (90 day moist room), B (14 day moist room) and C (7 day moist room and 7 day 50% humidity) type curing for the R-11-Z program of durability of concrete using the automatic freeze and thaw machine (ASTM C-291) has been used in the Materials Department of the Iowa State Highway Commission since December 6, 1966.

A summary of the results obtained from then until March 25, 1968 (Table 1), indicates that the B and C type curing are yielding very little valuable information. However, the A cure exhibits a wide range of durability factors and also groups the aggregates in an order which is related to the service record (there are definite exceptions). The biggest disadvantage to the A cure is the length of time that it takes to complete the test (90 day cure and 38 day test).

The Kansas Highway Department has experimented with different cements and aggregates in order to determine which combination offers a concrete with the best durability factor possible. In an experimental test section of highway, concrete made with a Type II cement appeared to have better durability than others made with Type I cements.[1] Because of this, a question has been raised at the Iowa State Highway Commission - Can concrete made with Type II cements, because of a lesser amount of tricalcium aluminate, yield better durability than concrete made with Type I cements?

2.0 PURPOSE

The purpose of this project is twofold:

(1) An effort will be made to determine if several different curing conditions and treatments prior to testing will give results similar to those of the A cure (related to service records) in a shorter period of time.

(2) The effect of Type II cements on the durability of concrete will also be studied.

3.0 MATERIALS

Coarse aggregate from eight different locations was used for this study. These materials were produced at the locations and had the properties

[1] Stingley, J.D. et al., "The McPherson Test Road: Tenth-Year Report" Highway Research Board Proceedings, 39:191-204(1960).

as follows:

Producer	Source	Lab Number	Specific Gravity (S.S.D.)	% Absorption (S.S.D.)	% Loss Method "A" Freeze & Thaw	% Wear, LA Abrasion, Grading B
Pella Limestone	Given Field Beds 16, 17, 18	AAC7-435	2.525	2.15	2.3	30
Henry Co. Quarry	Henry Co. Quarry Beds 8 - 11B	AAC8-21	2.564	2.05	1.3	27
Raid Quarries	Danville	AAC8-43	2.626	1.90	1.0	24
Concrete Materials	S. Cedar Rapids Quarry, Bed #4	AAC8-66	2.642	2.30	0.2	26
DeWees-Potthoff	Plower Quarry	AAC8-184	2.736	1.05	2.5	23[2]
W.A. Schemmer	Logan, Iowa	AAC8-222	2.616, 2.622	1.90	1.5	27
Roverud Const. Co.	Bente (Elkader) Quarry	AAC8-249	2.635, 2.642	2.66	1.7	41
Kuhlman Const. Co.	Osterdock Quarry	AAC8-250	2.646	2.00	3.3	32

The following cements were used:

Cement	Lab Number	% Tricalcium Aluminate
R-11 Blend[3]	AC7-5638 Chem. Analysis AC9-282	6.68
Penn-Dixie High Early	- - -	- -
Penn-Dixie Type I	AC9-365	7.97
Penn-Dixie Type II	- - -	7.67
Lehigh Type II	- - -	7.14
Ash Grove Type II	- - -	6.26

A fine aggregate (AAS7-41) from Hallett's Pit at Ames was used in the concrete. It complied with Section 4110 of the Standard Specifications and had the following gradation:

Sieve Size	% Passing
3/8"	100
#4	99+
#8	94
#16	70
#30	35
#50	8.2
#100	0.8
#200	0.4

[2]Grading A
[3]A blend of equal proportions of seven Type I cements.

Ad-Aire, a neutralized vinsol resin manufactured by the Carter-Waters Corporation and tested under laboratory number ACA6-20, was used an an air-entraining agent in the concrete.

4.0 LABORATORY PROCEDURE

All concrete mixed for this study was made using C-3 mix proportions as specified under Article 2301.04 in the Standard Specifications.

The coarse aggregate was in a saturated surface dry condition for mixing. It had 100% passing the 1" screen, with the aggregate retained being discarded unless the quantity was in excess of 10% of the total. In such a case, a test would be made to determine if crushing the excess aggregate and returning it to the sample would yield a substantially different durability factor.

The mixing procedure used was as follows:

1. Proportion sand and cement
2. Mix for one minute
3. Proportion coarse aggregate
4. Mix for one minute
5. Add water and air-entraining agent to adjust to a slump of 3" $\pm$ ½" while mixing for three minutes.

The air content of the concrete was determined by using the pressure method (ASTM C-231).

For the curing method study, sets of three 4"x4"x18" beams were made from each type of coarse aggregate for each curing method to be observed.[4] Consolidation in the molds was by an external platform vibrator. The beams were removed from the molds at an age of 20 - 24 hours.

Four methods of curing were studied. They were:

1. Cure A - The present 90 day moist room
2. Cure D - 45 day moist room
3. Cure E - 30 day moist room
4. Cure F - 14 day moist room followed by vacuum saturation.

The following procedure was used for the A, D and E cures:

1. Remove from molds after 20-24 hours
2. Moist room for 90, 45 or 30 days
3. 1 day in cooler. (40°F. water bath)

[4] Sets were not made for D and E cures using coarse aggregate from the Henry County Quarry, Raid Quarries or Concrete Materials.

The procedure for the F cure was as follows:

1. Remove from molds after 20 hours
2. 14 days in moist room
3. 2 hours of vacuum saturation
   a. ½ hour under air vacuum
   b. ½ hour under water vacuum
   c. 1 hour in water after vacuum released
4. 1 day in cooler. (40°F. water bath)

Sets of three 4"x4"x18" beams were also made for the Type II cement study. Three sets of beams were made with each type of cement[5] using coarse aggregate from a different source for each set. (The coarse aggregates were from W.A. Schemmer, Roverud Construction Company and Kuhlman Construction Company.) Consolidation and removal of the beams was done exactly as for the curing method study.

The beams were cured using an A cure - 90 days in the moist room.

Durability factors were computed using ASTM C-291 with the following exceptions:

1. The beams were 18" long
2. They were normally read at 56 cycle intervals
3. Their locations in the freezer were unchanged.

5.0 INTERPRETATION OF RESULTS

The following results were obtained from the method of curing study:

	Durability Factor			
Producer	Cure A	Cure D	Cure E	Cure F
Pella Limestone	98	101	98	99
Henry Co. Quarry	92	- -	- -	96
Raid Quarries	84	- -	- -	94
Concrete Materials	95	- -	- -	100
DeWees & Pothoff	76	95	99	96
W.A. Schemmer	42	72	72	80
Roverud Const.	66	81	93	94
Kuhlman Const.	29	78	85	96

[5]Penn-Dixie High Early was inadvertently used in place of Penn-Dixie Type I when using the coarse aggregate from W.A. Schemmer; therefore, there is one set of beams made with Penn-Dixie High Early and two sets made with Penn-Dixie Type I.

These results show that none of the cures tested give results which correlate the durability factors with the service records as well as the present A cure.

The results of the Type II cement study are given in the following table:

Cement	Coarse Aggregate, Producer: W.A. Schemmer (Durability Factor)	Roverud Constr. (Durability Factor)	Kuhlman Constr. (Durability Factor)	% Tricalcium Aluminate
Lehigh Type II	52	65	26	7.14
Penn-Dixie Type II	38	55	42	7.67
Ash Grove Type II	81	60	65	6.26
Penn-Dixie High Early	86	--	--	----
Penn-Dixie Type I	--	41	48	7.97
R-11 Blend	55	69	76	6.68

These results show that no cement has a particular advantage over the others because durability factors obtained using it are consistently better. However, a better durability factor appears to result from concrete made with cement having a lower percentage of tricalcium aluminate.

6.0 SUMMARY

This study has shown that:

(1) The experimental cures could not correlate durability factors with service records well enough to justify adopting one of them as a replacement for the A cure.

(2) Type II cements do not appear to yield concrete with better durability factors than can be obtained with Type I cements.

(3) The amount of tricalcium aluminate in cement appears to have an inverse effect on concrete durability. Further study is necessary, however, in order to reach definite conclusions.

7.0 TABLES

Table I

R-11-Z

Quarry Identification	Lab. No. AAC-	A Cure (90 day M.R.)	Previous (90 day M.R.)	Service Record Rating[6]	B Cure (14 day M.R.)	C Cure 7 day M.R. 7 day C. L.
Le Claire	7-14	99	94	1	102	101
Portland	6-519	97	97	1	100	102
Linwood	7-41	97	--	1	98	101
Klinkenberg	7-297	97	--	2	100	100
Dannett	7-42	96	--	2	102	100
Dytrt	6-498	95	97-92	2	94	97
Alden	7-195	94	93	1	99	96
MarJo Hills	6-522	94	--	1	99	97
Coppock (Spgn)	7-50	94	--	2	100	100
Menlo	6-341[7]	94[7]	71-11	4	99[7]	--
Douds						
Mt. Pleasant	7-100	94	87-69-89	2	96	99
Nashua	7-328	90	--	2	98	99
Malcom	7-24	88	81	2	98	100
Dubuque	7-36	88	91-78	1	98	95
Conklin	7-225	88	29	1	96	99
Ollie	7-47	85	80-32 (Cherty)	2	88	97
Montour	6-506	83	--	1	97	102
Columbus Jct.	6-507	85	--		92	97
	7-26	79	--	4	100	92
Moscow	7-333	79	54-44-62	1	100	104
Bente	7-35	74	61	3	98	90
Osterdock	7-199	73	--	3	98	98
Plower	6-494	44	56-24(Otis)	4	96	97
Newton	6-500	38	--	4	98	99
71 Quarry	7-301	35	--	4	97	99
Kereford	6-499	29	--	3	56	87
Coppock (St.L)	7-49	26	--	2	42	97
Grace Hill	7-48	25	27-30-6	2	69	51

[6]Service Record Ratings
1. Very good
2. Good
3. Fair
4. Poor

[7]Used from old sample and run for R-230A